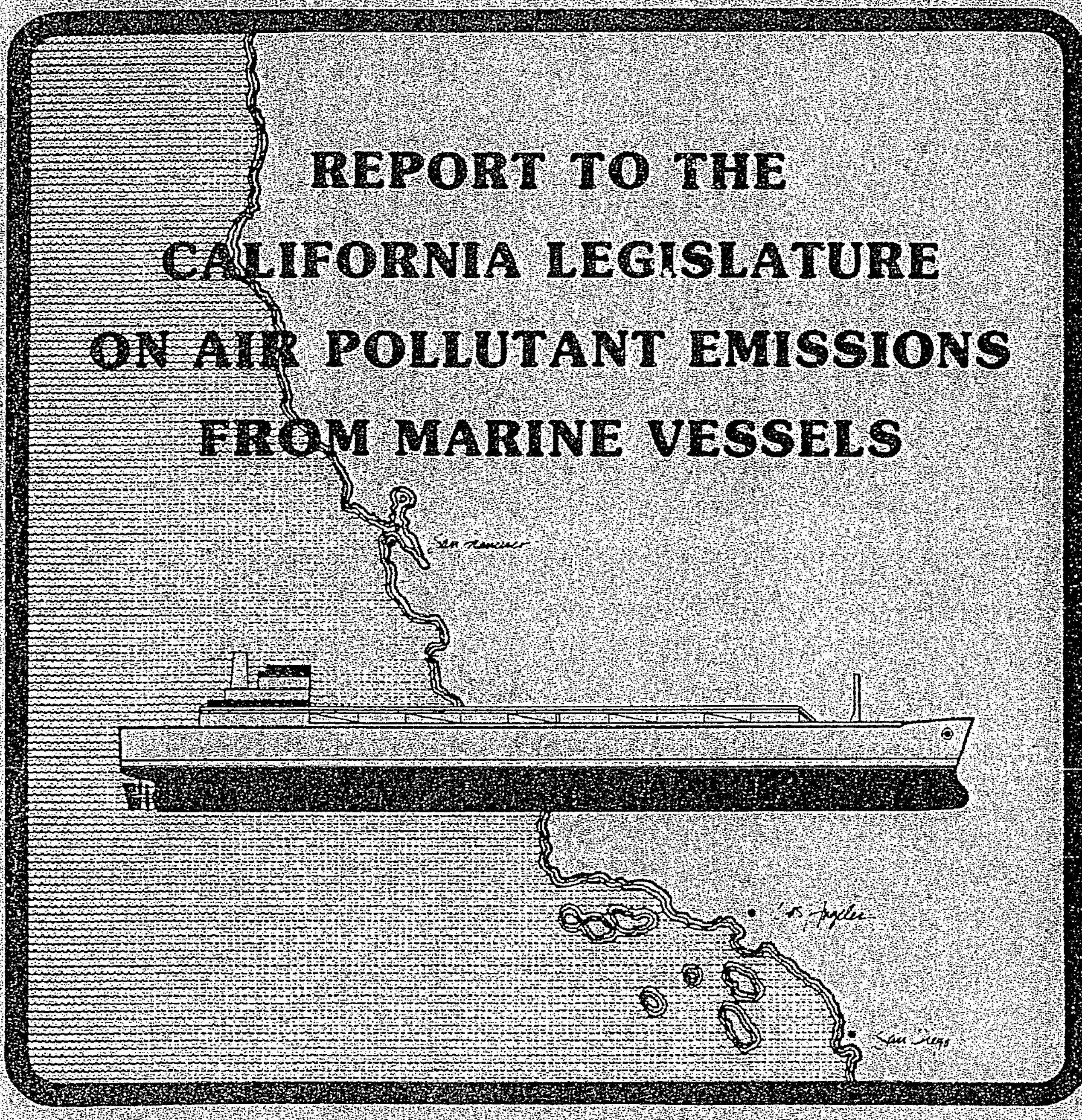
State of California

AIR RESOURCES BOARD

REPORT TO THE CALIFORNIA LEGISLATURE ON AIR POLLUTANT EMISSIONS FROM MARINE VESSELS



Volume I

June 1984

C. COASTAL CALIFORNIA METEOROLOGY

California Coastal Waters have been defined as that area between the California coastline and a line starting at the California - Oregon border at the Pacific Ocean

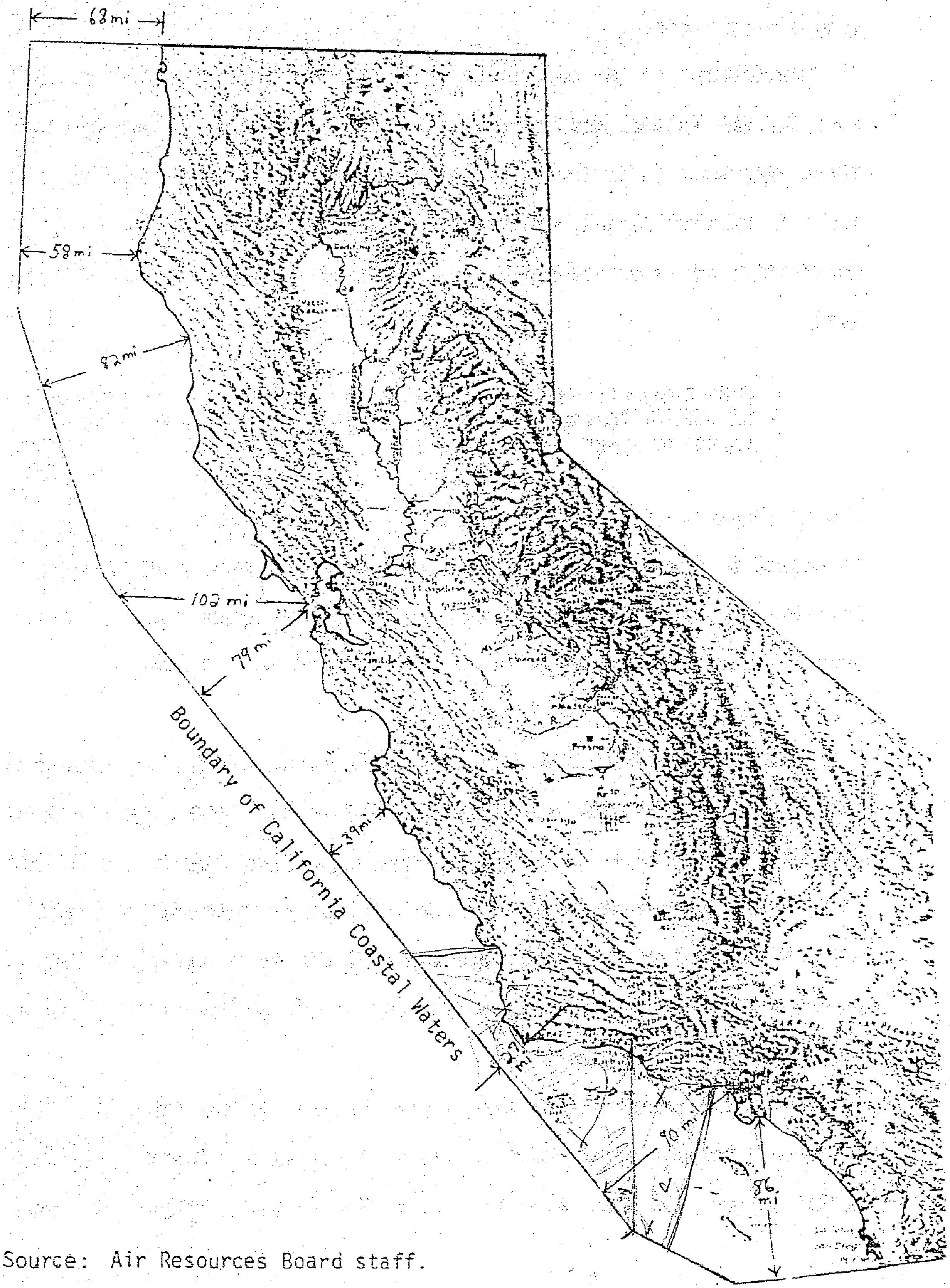
thence to 42.0° 125.5°W
thence to 41.0°N 125.5°W
thence to 40.0°N 125.5°W
thence to 39.0°N 125.0°W
thence to 38.0°N 124.5°W
thence to 37.0°N 123.5°W
thence to 36.0°N 122.5°W
thence to 35.0°N 121.5°W
thence to 34.0°N 120.5°W
thence to 33.0°N 119.5°W
thence to 32.5°N 118.5°W

and ending at the California-Mexico border at the Pacific Ocean. The California Coastal Waters are shown on Figure VI-6.

The line describing California Coastal Waters does not form a political boundary but it is useful in describing the fate of pollutants emitted off the California coast. The definition of California Coastal Waters was developed by the ARB meteorology staff and was originally presented as Appendix A to the ARB staff report, Status Report Regarding Adoption by Local Air Pollution Control Districts of Rules for the Control of Emissions from Lightering Operations, February 23, 1978. California Coastal Waters as defined above is the area offshore of California within which pollutants are likely to be transported ashore and affect air quality in California's coastal air basins, particularly during the summer. Pollutant emissions released somewhat to the west of these waters in summer are likely to be transported southward, parallel to the coast. Most coastal marine traffic passes 3 to 15 miles from

FIGURE VI-6

CALIFORNIA COASTAL WATERS



Source: Air Resources Board staff.

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* This report is comprised of seven volumes. Volume One contains the Summary and Chapters I through VII; Volume Two contains Chapters VIII through XI; Volume Three contains Appendices A-1 through A-4; Volume Four contains Appendices A-5 through A-7; Volume Five contains Appendices A-8 through A-10, B and C; Volume Six contains Appendices D through G; and Volume Seven contains Appendices H through M.

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* The appendices are printed in five volumes. Volume Three contains Appendices A-1 through A-4; Volume Four contains Appendices A-5 through A-7; Volume Five contains Appendices A-8 through A-10, B, and C; Volume Six contains Appendices D through G; and Volume Seven contains Appendices H through M.

VI. NEED FOR EMISSIONS REDUCTIONS

A. PREFACE

Three meetings of the Marine Vessel Emissions Task Force were held to discuss the need to reduce emissions from marine vessels. The following sections of this chapter detail industry views and staff findings. State and federal ambient air quality standards are outlined along with the need and bases of the standards. The extent of violations of the standards occurring in California coastal air basins is presented. Coastal California meteorology, including the Pacific high pressure cell, wind flow patterns, land/sea breezes, atmospheric inversions, and fog, is discussed in relation to the transport of pollutants. Evidence from studies in which inert gases were released from vessels offshore and the paths of the inert gases were traced to shore (tracer studies) is presented. Results of mathematical modeling of emissions from marine vessels are given. Finally, the impact of emissions from marine vessels on ambient air quality is assessed.

B. EXISTING AMBIENT AIR QUALITY

1. Ambient Air Quality Standards and Air Quality Monitoring

Recognizing that certain minimum standards are required to protect the public health and welfare, national and state ambient air quality standards have been established. The Clean Air Act of 1970 authorizes the U. S. Environmental Protection Agency (EPA) to set standards and to oversee the development and implementation of state plans that would lead to attainment and maintenance of the nationwide standards.[1/] In addition, the Air Resources Board has established ambient air quality standards, as authorized by the California Health and Safety Code.[2/] Standards have been set for all major pollutants, including oxidant or ozone, nitrogen dioxide, sulfur dioxide, suspended particulate matter, and sulfates.

The federal and state standards have been established in consideration of public health, aesthetics, visibility, and effects on the economy.[2/] The EPA set primary standards to reflect consideration of public health and secondary standards to reflect consideration of public welfare. The Air Resources Board established one set of standards for each pollutant, based on both public health and welfare. Table VI-I lists the national and California standards. As the table shows, the state has set a standard for oxidant, whereas the national standard is for ozone; however, the state now measures ozone only and the state standard is, in effect, an ozone standard. Ozone is a pollutant which is produced by chemical reactions of nitrogen oxides and hydrocarbons in the presence of sunlight. The table also shows that the state sulfur dioxide standard is different from the federal standard. The state standard is the occurrence of a 24-hour sulfur dioxide concentration of 0.05 ppm or higher in combination with either (1) an hourly ozone level equalling or exceeding 0.10 ppm or (2) a 24-hour concentration of total suspended particulate (TSP) equalling or exceeding 100 ug/m^3. Violation of the 24-hour federal sulfur dioxide standard of 0.14 ppm does not require the presence of high concentrations of ozone or TSP. Table VI-1 also shows that the state annual geometric mean and 24-hour TSP standards are more stringent than their federal counterparts. Also, the state standard for nitrogen dioxide is set for a different averaging time than the federal standard. The table also shows that the state has a standard for sulfates, whereas there is currently no national standard for this pollutant.

The Air Resources Board and air pollution control and air quality management districts have established ambient air quality monitoring stations

TABLE VI-1

AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	California Standards[1]		National Standards[2]		
		Concentration[3]	Method[4]	Primary[3,6]	Secondary[3,4]	Method[7]
Oxidant[10]	1 hour	0.10 ppm (200 ug/m³)	Ultraviolet Photometry	—	—	—
Ozone	1 hour	—	—	0.12 ppm (235 ug/m³)	Same as Primary Standard	Ethylene Chemiluminescence
Carbon Monoxide	8 hour	9.0 ppm (10 mg/m³)	Non-Dispersive Infrared Spectroscopy (NDIR)	10 mg/m³ (9 ppm)	Same as Primary Standards	Non-Dispersive Infrared Spectroscopy (NDIR)
	1 hour	20 ppm (23 mg/m³)		40 mg/m³ (35 ppm)		
Nitrogen Dioxide	Annual Average	—	Gas Phase Chemiluminescence	100 ug/m³ (0.05 ppm)	Same as Primary Standard	Gas Phase Chemiluminescence
	1 hour	0.25 ppm (470 ug/m³)		—		
Sulfur Dioxide	Annual Average	—	Ultraviolet Fluorescence	80 ug/m³ (0.03 ppm)	—	Pararosaniline
	24 hour	0.05 ppm (131 ug/m³)[9]		365 ug/m³ (0.14 ppm)	—	
	3 hour	—		—	1300 ug/m³ (0.5 ppm)	
	1 hour	0.5 ppm 1/ (1310 ug/m³)		—	—	
Suspended Particulate Matter	Annual Geometric Mean	60 ug/m³ 1/	High Volume Sampling	75 ug/m³	60 ug/m³	High Volume Sampling
	24 hour	100 ug/m³ 1/		260 ug/m³	150 ug/m³	
Sulfates	24 hour	25 ug/m³	Turbidimetric Barium Sulfate	—	—	—
Lead	30 day Average	1.5 ug/m³	Atomic Absorption	—	—	—
	Calendar Quarter	—	—	1.5 ug/m³	Same as Primary Standard	Atomic Absorption
Hydrogen Sulfide	1 hour	0.03 ppm (42 ug/m³)	Cadmium Hydroxide STRactan	—	—	—
Vinyl Chloride (Chloroethene)	24 hour	0.010 ppm (26 ug/m³)	Tedlar Bag Collection, Gas Chromatography	—	—	—
Visibility Reducing Particles	1 observation	In sufficient amount to reduce the prevailing visibility[8] to less than 10 miles when the relative humidity is less than 70%		—	—	—
APPLICABLE ONLY IN THE LAKE TAHOE AIR BASIN:						
Carbon Monoxide	8 hour	6 ppm (7 mg/m³)	NDIR	—	—	—
Visibility Reducing Particles	1 observation	In sufficient amount to reduce the prevailing visibility[8] to less than 30 miles when the relative humidity is less than 70%		—	—	—

(Footnotes on following page.)

Source: Air Resources Board staff.

TABLE VI-1

AMBIENT AIR QUALITY STANDARDS
(Continued)

NOTES:

a/ California standards, other than carbon monoxide, are values that are not to be equaled or exceeded. The carbon monoxide standards are not to be exceeded.

b/ National standards, other than ozone and those based on annual averages or annual geometric means, are not to be exceeded more than once a year. The ozone standard is attained when the expected number of days a calendar year with a maximum hourly average-concentration above the standard is equal to or less than one.

c/ Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury. All measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 mm of Hg (1,013.2 millibar); ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

d/ Any equivalent procedure which can be shown to the satisfaction of the Air Resources Board to give equivalent results at or near the level of the air quality standard may be used.

e/ National Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health. Each state must attain the primary standards no later than three years after that state's implementation plan is approved by the Environmental Protection Agency (EPA).

f/ National Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Each state must attain the secondary standards within a "reasonable time" after the implementation plan is approved by the EPA.

g/ Reference method as described by the EPA. An "equivalent method" of measurement may be used but must have a "consistent relationship to the reference method" and must be approved by the EPA.

h/ Prevailing visibility is defined as the greatest visibility which is attained or surpassed around at least half of the horizon circle, but not necessarily in continuous sectors.

i/ At locations where the state standards for oxidant and/or suspended particulate matter are violated. National standards apply elsewhere.

j/ Measured as ozone.

k/ On November 18, 1983, the Board approved a new 1-hour standard for ambient concentrations of sulfur dioxide of 0.25 ppm or about 655 ug/m^3. That standard will be in effect following its approval by the Office of Administrative Law.

l/ New California suspended particulate matter standards became effective in December 1983. The standards are for suspended particulate matter smaller than 10 microns in diameter. The standards for particles in that size are 30 ug/m^3 annual geometric mean and 50 ug/m^3 for a 24-hour period.

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in the coastal air basins. The data from these stations are used to determine whether ambient air quality standards have been violated in specific areas. Figure VI-1 shows all of the coastal monitoring stations that were operating during 1981. The figure shows that monitoring stations are widely distributed on the coast and that numerous stations are operated in the major metropolitan areas of the South Coast and San Francisco Bay Area Air Basins.

2. Health Effects of Pollutants

The emissions that are of chief concern in this report are sulfur dioxide and hydrocarbons. The health effects of sulfur dioxide and the secondary pollutants produced from sulfur dioxide and hydrocarbons are discussed below.

a. Sulfur Dioxide

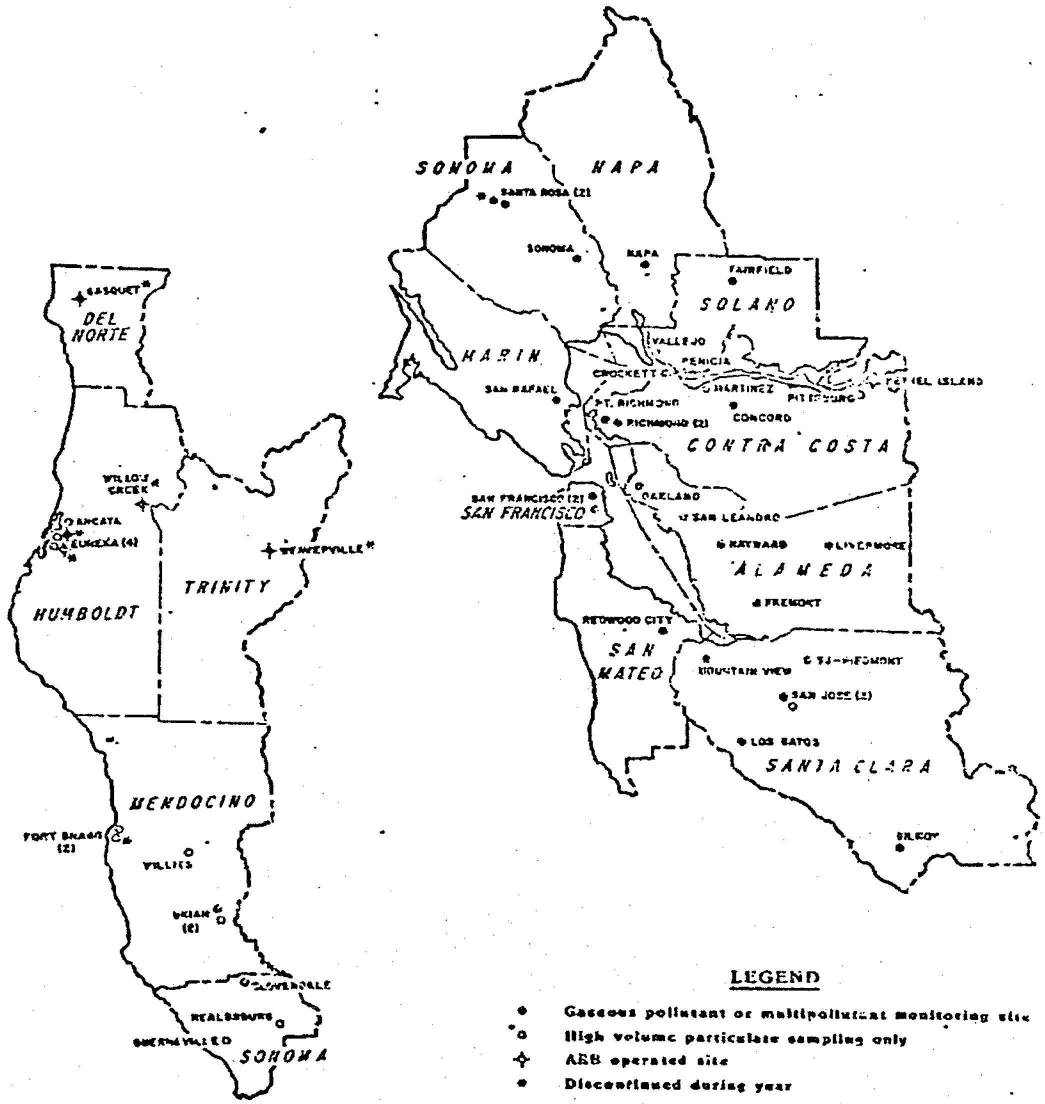
Sulfur dioxide alone is a mild respiratory irritant. Reactions to exposure to sulfur dioxide have been shown to be more severe in persons with asthma, especially in conjunction with exercise. The principal effect measured is bronchoconstriction or a tightening of the airways in the lungs which results in increased airway resistance.[3,4,5,6]

Epidemiological studies have shown sulfur dioxide to be associated with the development and exacerbation of chronic respiratory conditions, especially when combined with particulate matter. Children have been shown to have a significantly higher prevalence and history of respiratory infections when exposed to sulfur dioxide and particulate matter pollution.[7,8]

b. Sulfates

Sulfur dioxide can be oxidized in the atmosphere to form sulfate particles. Sulfates are normally found in the "fine" fraction of suspended particulate matter (diameter less than 2.5 micrometers) and therefore are in the size range that can be inhaled into the respiratory system.[9] There is

SAN FRANCISCO BAY AREA AIR BASIN
MONITORING STATIONS OPERATING DURING 1981



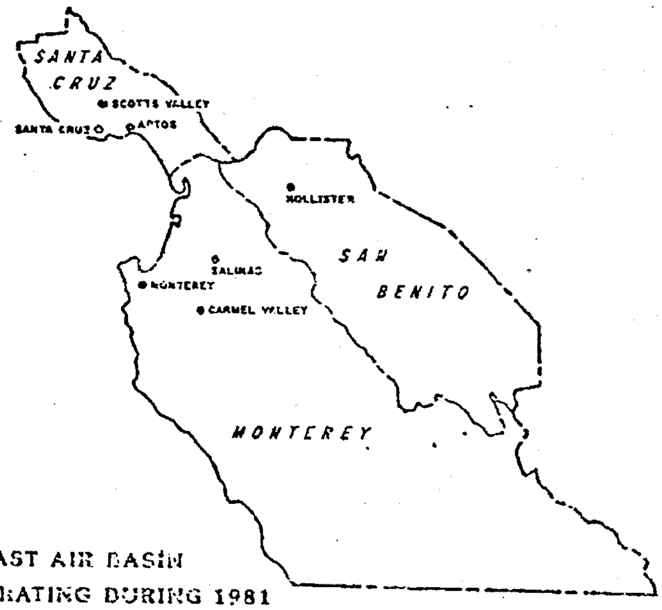
NORTH COAST AIR BASIN
MONITORING STATIONS OPERATING DURING 1981

FIGURE VI-1

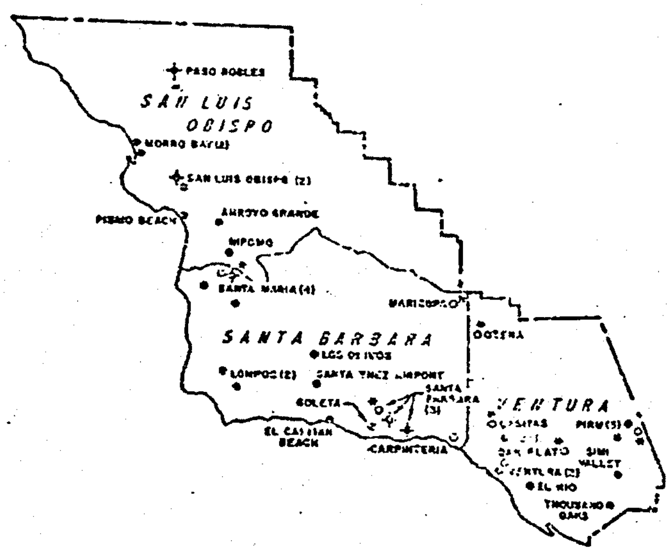
AIR QUALITY MONITORING STATIONS
IN CALIFORNIA'S COASTAL AIR BASINS

Source: Air Resources Board staff.

NORTH CENTRAL COAST AIR BASIN
MONITORING STATIONS OPERATING DURING 1981



SOUTH CENTRAL COAST AIR BASIN
MONITORING STATIONS OPERATING DURING 1981



LEGEND

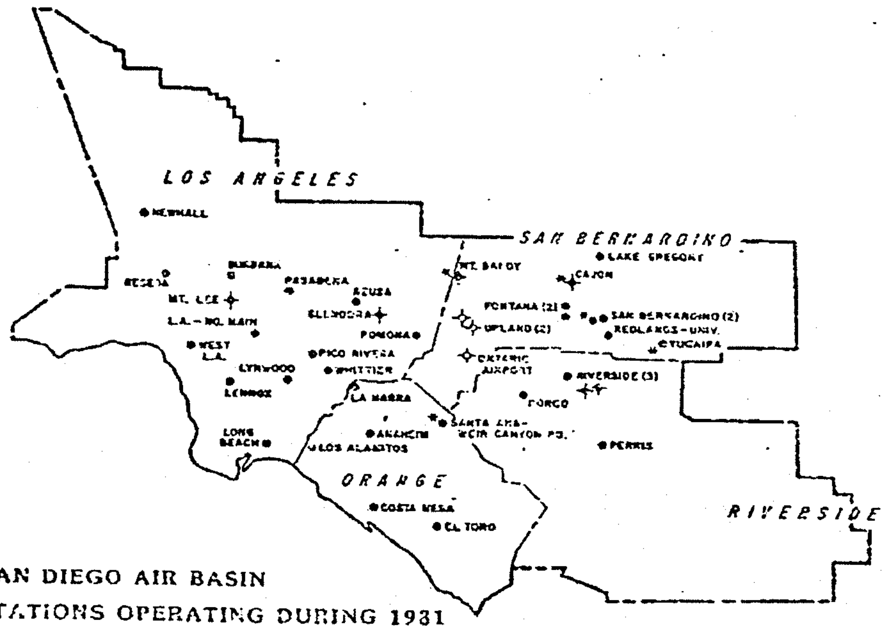
- ● Gaseous pollutant or multipollutant monitoring site
- ○ High volume particulate sampling only
- ARB operated site
- * Discontinued during year

FIGURE VI-1
(Continued)

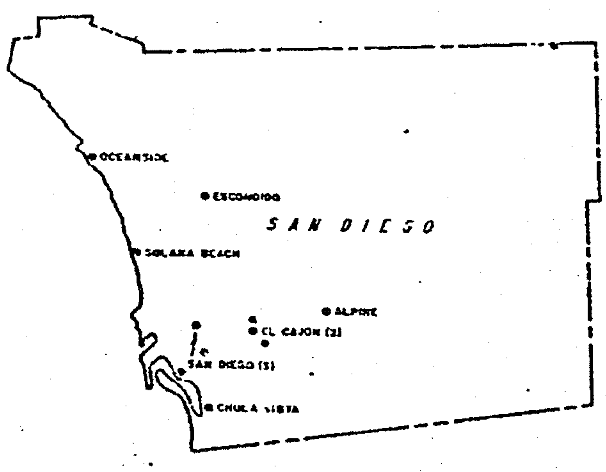
AIR QUALITY MONITORING STATIONS
IN CALIFORNIA'S COASTAL AIR BASINS

Source: Air Resources Board staff.

SOUTH COAST AIR BASIN
MONITORING STATIONS OPERATING DURING 1981



SAN DIEGO AIR BASIN
MONITORING STATIONS OPERATING DURING 1981



LEGEND

- ● Gaseous pollutant or multipollutant monitoring site
- ○ High volume particulate sampling only
- ✦ ARB operated site
- ● Discontinued during year

FIGURE VI-1
(Continued)

AIR QUALITY MONITORING STATIONS
IN CALIFORNIA'S COASTAL AIR BASINS

Source: Air Resources Board staff.

limited dose-response information available for effects attributable directly to sulfates but they are believed to aggravate asthma, lung, and heart disease, and lung function in children. In addition to the particle size, effects may be influenced by other variables such as weather conditions (e.g., high humidity enhances sulfate formation) and the presence of other pollutants.[10/]

c. Suspended Particulate Matter

Sulfur dioxide and hydrocarbons are, at least in part, converted in the atmosphere to suspended particulate matter. Particles small enough to be inhaled into the respiratory system (diameter less than 10-15 micrometers) are of most concern for health protection. Suspended particulate matter may cause adverse effects by a number of mechanisms. These mechanisms include chemical or mechanical irritation, alteration of host defense mechanisms (e.g., clearance mechanisms), direct or indirect damage (e.g., acid aerosols, silica) or systemic toxicity (e.g., lead). The resulting effects associated with exposure to particulate matter include effects on respiratory mechanics, aggravation of existing respiratory and cardiovascular disease, effects on clearance and other host defense mechanisms, morphological alterations, carcinogenesis, and mortality.[9,11/]

d. Ozone

Ozone is formed in the atmosphere by chemical reactions of two other pollutants, hydrocarbons and nitrogen oxides. These reactions require energy which is provided by sunlight. Ozone, the largest component of the smog complex, is a strong respiratory irritant. It irritates the mucous membrances of the respiratory system and impairs normal function of the lung. This impairment is accompanied by such symptoms as chest tightness, coughing, and wheezing. Ozone has been shown to aggravate chronic respiratory diseases such as asthma and bronchitis. Peroxyacetal nitrates (PAN) and the other oxidants formed in the atmosphere along with ozone are strong eye irritants.[12/]

3. Coastal California Air Quality

All of the coastal air basins in California experience violations of ambient air quality standards. Table VI-2 is a compendium of the ambient air quality in California coastal air basins for ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, sulfate, and total suspended particulate (TSP) during the period 1979 through 1981. The data presented in Table VI-2 are discussed below.

a. Violations of State and Federal Standards

The one hour national ambient air quality standard for ozone of 0.12 ppm was exceeded in all of California's coastal air basins from the San Francisco Bay Area southward in the years 1979 through 1981. The frequency of the violations in 1981 ranged from 2 days in the North Central Coast Air Basin to 187 days in the South Coast Air Basin. The California standard for oxidant (measured as ozone) of 0.10 ppm was exceeded in all coastal air basins during the period 1979 through 1981. The frequency of the violations in 1981 ranged from 8 days in the North Central Coast Air Basin, to 233 days in the South Coast Air Basin.

Violations of the California standard for nitrogen dioxide, 0.25 ppm for 1 hour, occurred in the San Francisco Bay Area, South Coast, and San Diego Air Basins in the period 1979-1981. The most frequent violations occurred in the South Coast Air Basin. The nitrogen dioxide standard was violated on 44 and 38 days in the South Coast Air Basin in 1980 and 1981, respectively. The annual average national ambient air quality standard for nitrogen dioxide of

TABLE VI-2

SUMMARY OF AIR QUALITY IN COASTAL AIR BASINS

1979-1981

POLLUTANT	CONCENTRATION	North Coast			San Francisco Bay Area			North Central Coast			South Central Coast			South Coast			San Diego		
		1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
OZONE	One Hour Avg ≥.10 ppm (days)	1	0	0	60	46	51	5	15	8	146	143	151	228	210	233	138	167	192
	One Hour Avg ≥.12 ppm (days)	0	0	0	15	18	8	0	2	2	73	61	85	193	167	187	66	87	76
	High (ppm)	.10	.08	.09	.19	.20	.18	.10	.14	.14	.23	.21	.24	.47	[illegible]	.39	.36	.23	.29
	Second High (ppm)	.09	.08	.09	.17	.19	.18	.10	.14	.14	.22	.20	.23	.46	.44	.37	.36	.23	.26
	One Hour Avg ≥.20 ppm (days)	0	0	0	0	1	0	0	0	0	2	1	3	123	102	105	10	8	2
CARBON MONOXIDE	Eight Hour Avg >9.3 ppm (days)	0	0	--	20	15	6	0	0	0	7	6	0	94	94	80	10	1	1
	12 Hour Avg ≥10 ppm (days)	0	0	--	10	5	1	0	0	0	0	0	0	62	60	59	0	0	0
NITROGEN DIOXIDE	One Hour Avg ≥.25 ppm (days)	--	--	0	0	1	0	0	0	0	0	0	0	76[a]	44	38	0	0	1
SULFUR DIOXIDE	24 Hour Avg ≥.05 ppm (days)	--	--	0	0	0	0	1	0	0	0	0	0	13[b]	2[b]	0	0	0	0
	High (ppm)	--	--	.003	.027	.039	.033	.057	.003	.008	.035	.033	.038	.079	.068	.044	.040	.042	.028
	Second High (ppm)	--	--	.002	.025	.035	.026	.044	.002	.006	.033	.030	.036	.079	.051	.041	.040	.036	.027
	One Hour Avg ≥.5 ppm (days)	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	High (ppm)	--	--	.02	.12	.14	.09	.24	.02	.02	.12	.17	.27	.18	.17	.16	.09	.13	.12
	Second High (ppm)	--	--	.01	.11	.14	.09	.12	.01	.02	.11	.17	.23	.17	.16	.14	.07	.11	.10
SULFATE	24 Hour Avg ≥25 μg/m³ (days)	0	0	0	0	0	0	0	0	0	0	3	0	22	35	18	0	2	0
	Number of Sampling Days	61	53	53	71	69	65	62	59	60	140	147	146	361	366	359	63	65	53
	Percent ≥ 25 μg/m³	0	0	0	0	0	0	0	0	0	0	2	0	6	10	5	0	3	0
	High (μg/m³)	7.9	7.5	6.2	17.7	16.0	16.3	14.8	8.7	7.3	19.5	31.0	22.7	37.9	50.2	48.4	14.2	28.2	23.7
	Second High (μg/m³)	7.4	7.5	5.6	15.7	15.2	15.6	14.0	8.5	6.1	19.2	29.3	21.8	36.1	50.2	42.4	14.1	27.9	15.5
	24 Hr Avg ≥25 μg/m³ combined with ozone one hour avg ≥.20 ppm (days)	0	0	0	0	0	0	0	0	0	0	0	0	7	26	6	0	0	0
TOTAL SUSPENDED PARTICULATE	24 Hour Avg ≥100 μg/m³ (days)	21	25	9	52	42	9	16	7	3	55	83	84	283	264	288	33	46	41
	Number of Sampling Days	65	68	81	162	123	69	63	61	62	152	161	207	365	366	362	65	79	86
	Percent ≥100 μg/m³	32	37	11	32	34	13	25	11	5	36	52	41	78	72	80	51	58	48
	High (μg/m³)	239	173	133	320	249	143	178	161	130	432	1366	518	417	511	602	180	225	271
	Second High (μg/m³)	190	165	132	262	216	127	155	132	100	340	476	456	386	505	[illegible]	169	199	237
	Percent ≥260 μg/m³	0	0	0	1	0	0	0	0	0	2	6	3	7	13	7	0	0	1

--Data not available.

[a] Measured nitrogen dioxide concentrations in 1979 were high due to a calibration bias. The standard exceedances in 1979 are not based on the adjusted concentrations. The number of standard violations is therefore less than 76 by an undetermined amount.

[b] California standard is 24 hours sulfur dioxide concentration ≥ 0.05 ppm in combination with a violation of either the state standard for ozone or total suspended particulate. Only one of the 1980 South Coast Air Basin measurements of sulfur dioxide ≥ 0.05 ppm was a probable violation; that is, the violation of the state TSP standard occurred at a nearby monitoring station. Twelve of the 13 measurements ≥ 0.05 ppm in 1979 were violations.

Source: Air Resources Board Technical Services Division.

0.05 ppm was also exceeded in the South Coast Air Basin in each of these three years.

The California 24-hour standard for sulfate of 25 ug/m^3 was violated in the South Central Coast, South Coast, and San Diego Air Basins in the period 1979-1981. Table VI-2 shows that in 1980 there were 3 measured sulfate violations in the South Central Coast Air Basin and 2 measured sulfate violations in the San Diego Air Basin. Because ambient sulfate measurements in those air basins were made on only 147 and 65 days, respectively, during 1980, it is reasonable to assume that, using proration, actual sulfate violations occurred on about 7 days in the South Central Coast Air Basin and 11 days in the San Diego Air Basin. There were 22 violations of the sulfate standard in the South Coast Air Basin in 1979, 35 in 1980, and 18 in 1981. The highest sulfate readings during this period occurred in 1980 and were twice the standard (50.2 ug/m^3). Sulfate standard violations were recorded at over 90 percent of the air monitoring stations at which sulfate was measured in the South Coast Air Basin during the period 1979 through 1981.

The 24-hour sulfate standard has not been violated in the past three years in the San Francisco Bay Area, North Central Coast, and North Coast Air Basins. Annual maximum 24-hour sulfate concentrations in 1979-1981 were 16.0 to 17.7 ug/m^3 in the San Francisco Bay Area Air Basin and 7.3 to 14.8 ug/m^3 in the North Central Coast Air Basin.

Since 1979, no sulfur dioxide standard violations have been recorded in California's coastal air basins. However, the California 24 hour sulfur dioxide standard, 0.05 ppm in combination with a high oxidant or TSP level, was violated on 12 days in the South Coast Air Basin during 1979, and one probable exceedance occurred in 1980. The highest 24-hour sulfur dioxide concentration during 1979-1981 was 0.079 ppm and occurred in 1979 at Harbor City, near the coast. A major reason for the low ambient concentrations of sulfur dioxide is the greatly increased availability of natural gas to power plants. By burning clean natural gas instead of sulfur-bearing fuel oil, emissions of sulfur dioxide have been greatly reduced. However, if the availability of natural gas is reduced in the future, sulfur-bearing fuel oil will have to be burned again and ambient concentrations of sulfur dioxide would increase.

Table VI-2 shows that all of the coastal air basins experienced numerous, and in some cases extreme, violations of the 100 ug/m^3 state standard for TSP during 1979 through 1981. Twenty-four hour TSP concentrations of 518 ug/m^3, 602 ug/m^3 and 271 ug/m^3 were recorded in 1981 in the South Central Coast, South Coast, and San Diego Air Basins respectively. These concentrations of TSP also exceed the national primary standard of 260 ug/m^3. Most of the air monitoring stations in the South Coast Air Basin experienced violations of the state 24-hour and federal annual TSP standards and more than 48 percent of those air monitoring stations experienced violations of the federal 24-hour TSP standard in the period 1979-1981.[13,14,15] Because TSP measurements are made with different frequencies in different air basins, the data on state TSP standard violation frequencies given in Table VI-2 are given in terms of percent of sampling days on which the TSP standard was violated. Since December 1983, the state standards for particulate matter have been based on particulates smaller than 10 microns in diameter. The annual 200 geometric mean and 24 hour standards are now 30 ug/m^3 and 50 ug/m^3 for suspended particulate matter smaller than 10 microns in diameter.

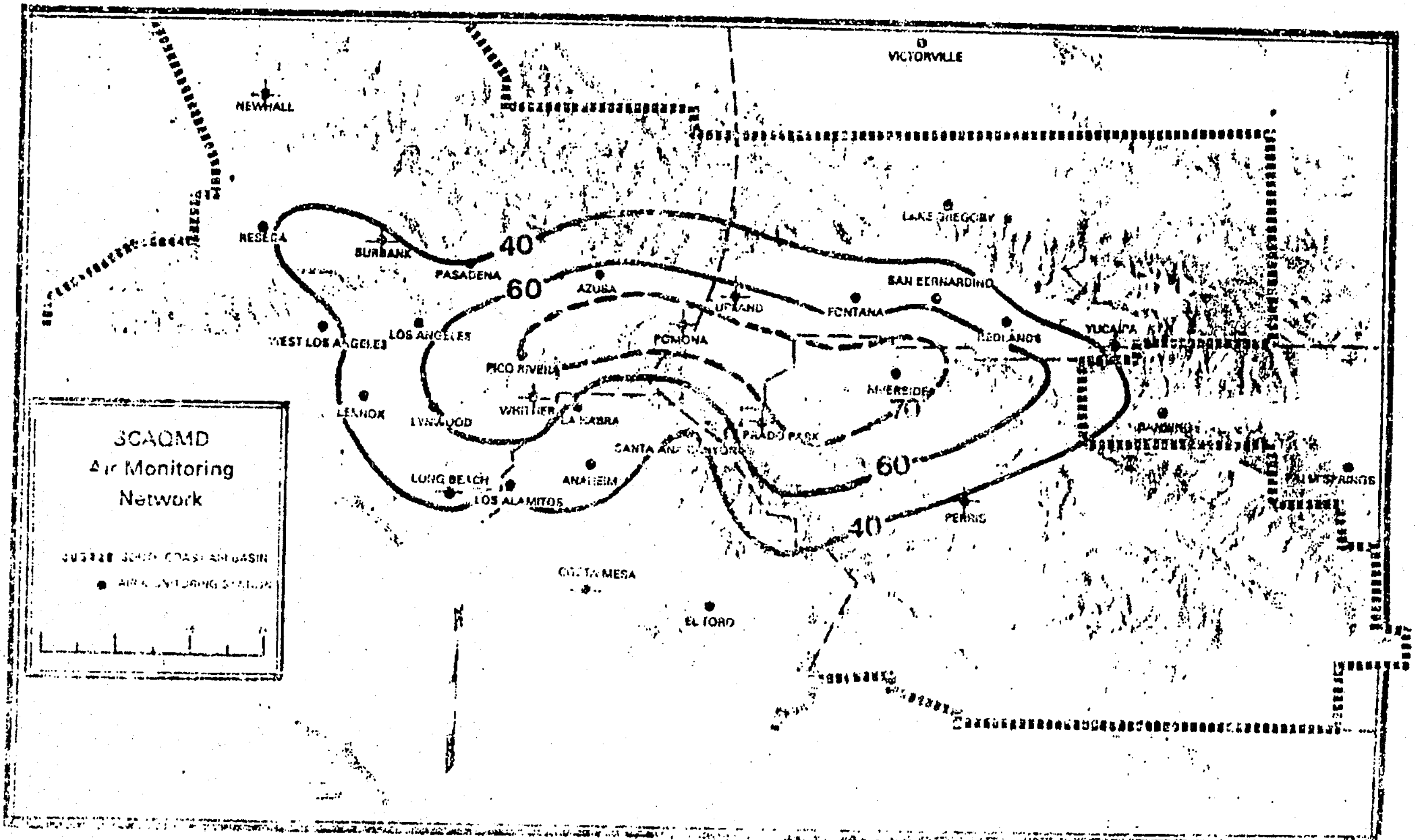
According to data in the annual ARB publications "California Air Quality Data"[13,14,15], sulfates contribute significantly to the annual geometric mean TSP mass. On an annualized basis, sulfate contributed from 6 to 15 percent of TSP in the South Coast Air Basin in 1979[16]. Two-hour "grab sample" air monitoring data reported for 1977[17] and 1973[18] show that sulfate accounted for 22 and 31 percent of the TSP measured at Anaheim and Dominguez Hills, respectively, in the South Coast Air Basin. Figures VI-2 and VI-3 show the frequency of violations in the South Coast Air Basin of the California sulfate standard and TSP standard respectively during 1980. Comparison of Figure VI-2 with VI-3 shows that sulfate and TSP violations occur with the greatest frequency in the same general areas.

The California visibility standard is exceeded when the prevailing visibility is reduced to less than 10 miles while the relative humidity is less than 70 percent. Figure VI-4 shows median 1 PM visibilities and visibility isopleths for California. The figure shows that coastal areas of California frequently experience visibilities in violation of the state standard. Table VI-3 shows the quarterly frequency of violation of the state visibility standard in coastal air basins in the period 1958-1977. The table shows that on a quarterly basis during that period the visibility standard was violated 10 to 42 percent of the time in the San Francisco Bay Area Air Basin, 6 to 52 percent of the time in the South Central Coast Air Basin, 15 to 63 percent of the time in the South Coast Air basin, and 21 to 37 percent of the time in the San Diego Air Basin. The visibility standard continues to be regularly violated throughout California's coastal areas.

Numerous studies have found that airborne particulate sulfates and nitrates contribute to visibility degradation in a ratio far exceeding the fraction of suspended aerosols represented by those species.[19,20,21,22]

FIGURE VI-2

TOTAL SUSPENDED PARTICULATE-1980
PERCENT OF DAYS ON WHICH STATE STANDARD WAS EXCEEDED
(24-HOUR AVERAGE TSP ≥ 100 $\mu g/m^3$)



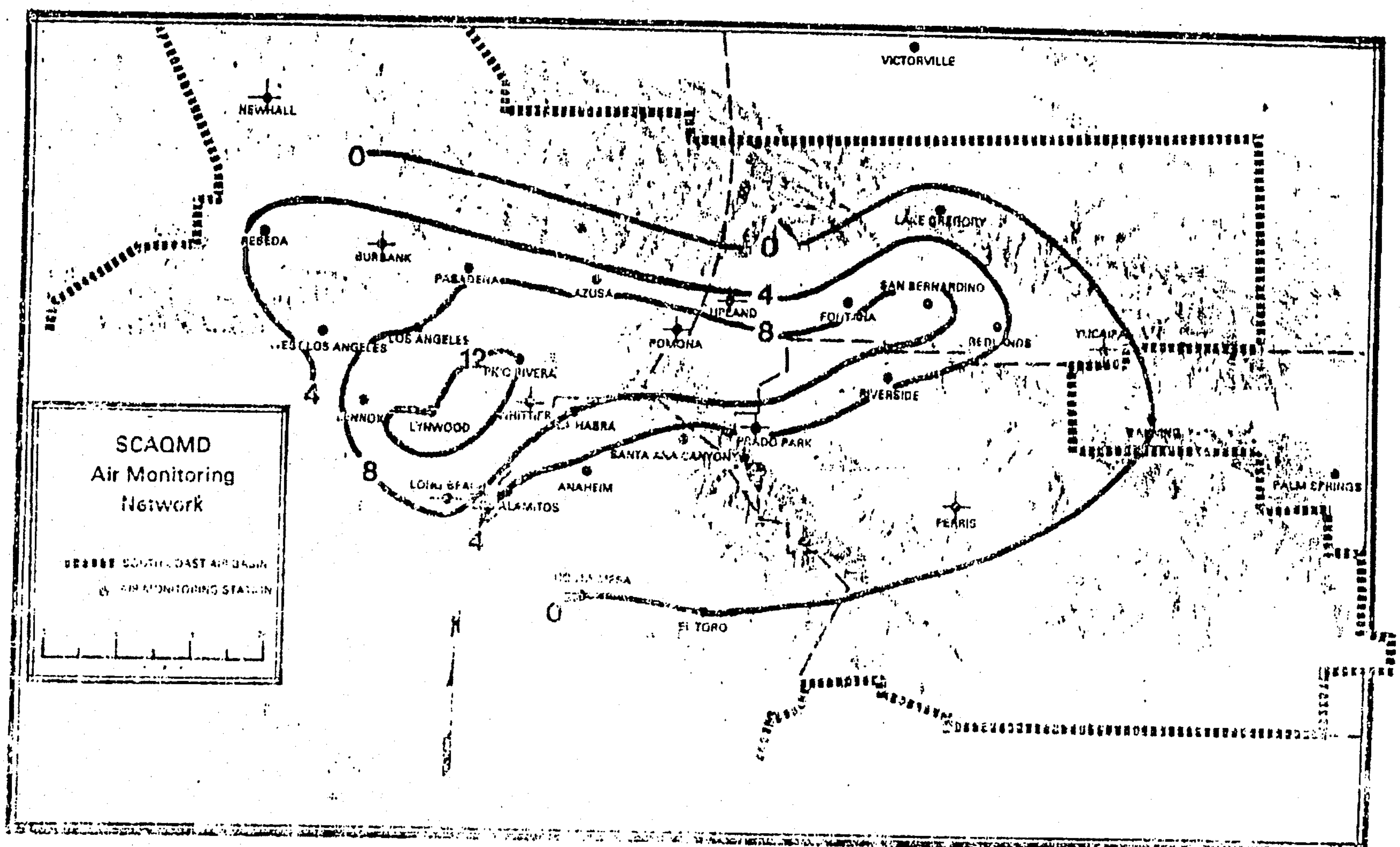
Source: Summary of Air Quality in the South Coast Air Basin of California, 1980, South Coast Air Quality Management District, May 1981

Less than 12 months of data.
Not measured at this location.
Total suspended particulate is measured every sixth day.

FIGURE VI-3

SULFATE-1980

PERCENT OF DAYS ON WHICH STATE STANDARD WAS EXCEEDED
(24-HOUR AVERAGE $SO_4^{=} \geq 25\ \mu g/m^3$)

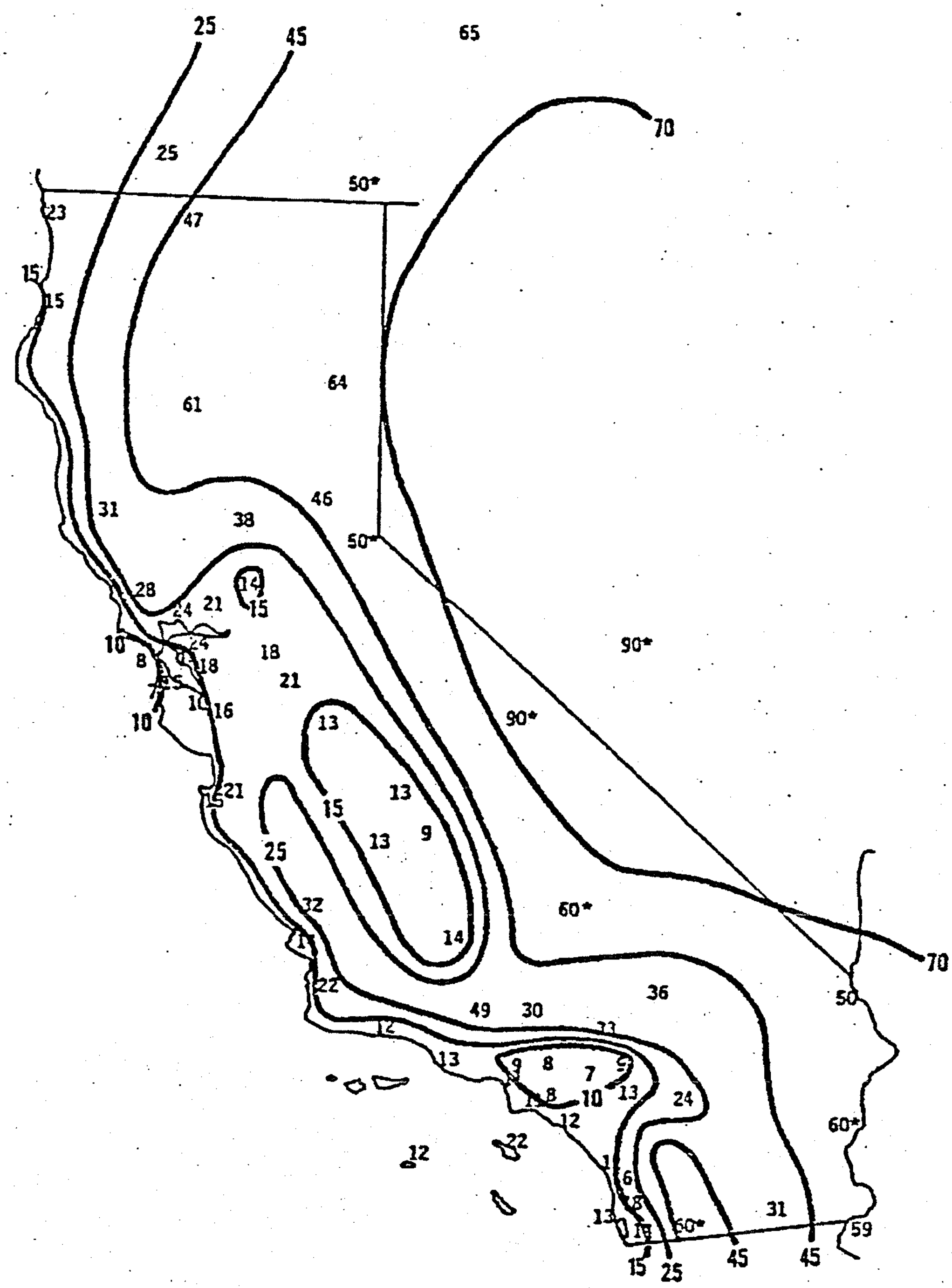


Source: Summary of Air Quality in the South Coast Air Basin of California, 1980, South Coast Air Quality Management District, May 1981.

Less than 12 months of data.
Not measured at this location.
Sulfate is measured every sixth day.

FIGURE VI-4

MEDIAN 1 PM VISIBILITIES (IN MILES) AND
VISIBILITY ISOPLETHS FOR CALIFORNIA



Source: Air Quality and Meteorology, South Coast Air Quality Management District, September 1979.

TABLE VI-3

20-YEAR PERCENTAGE OCCURRENCE OF ADVERSE VISIBILITIES
(1958-1977)

Station (north to south)	All-month average	Rank (best to worst)	Season a/ (percentage adverse) Worst	Best	Number of qualifying observations
San Francisco	21%	3	Winter (36%)	Spring (10%)	5633
Oakland	26%	4	Fall (42%)	Spring (14%)	4793
Salinas	8%	1	Fall (17%)	Spring (5%)	5969
Santa Maria	15%	2	Fall (22%)	Winter (6%)	6343
Oxnard	32%	6	Summer (52%)	Winter (19%)	4057
Los Angeles	49%	8	Summer (63%)	Spring (37%)	5511
Long Beach	51%	9	Summer (63%)	Spring (35%)	6599
Riverside	38%	7	Summer (60%)	Winter (15%)	6851
San Diego	29%	5	Summer (37%)	Spring (21%)	6190

a/ Seasons:

Winter = December, January, February
Spring = March, April, May
Summer = June, July, August
Fall = September, October, November

Source: Visibility Trends in the Coastal Areas of California 1958-1977, Air Resources Board Technical Services Division, December 1980.

This occurs because sulfate particulates are in the size range of particles that are effective in scattering light. It has been reported that on an average for 12 separate sampling sites throughout coastal and inland areas in California, 39 percent of the visibility degradation is due to suspended sulfates.[19/]

b. Acid Precipitation

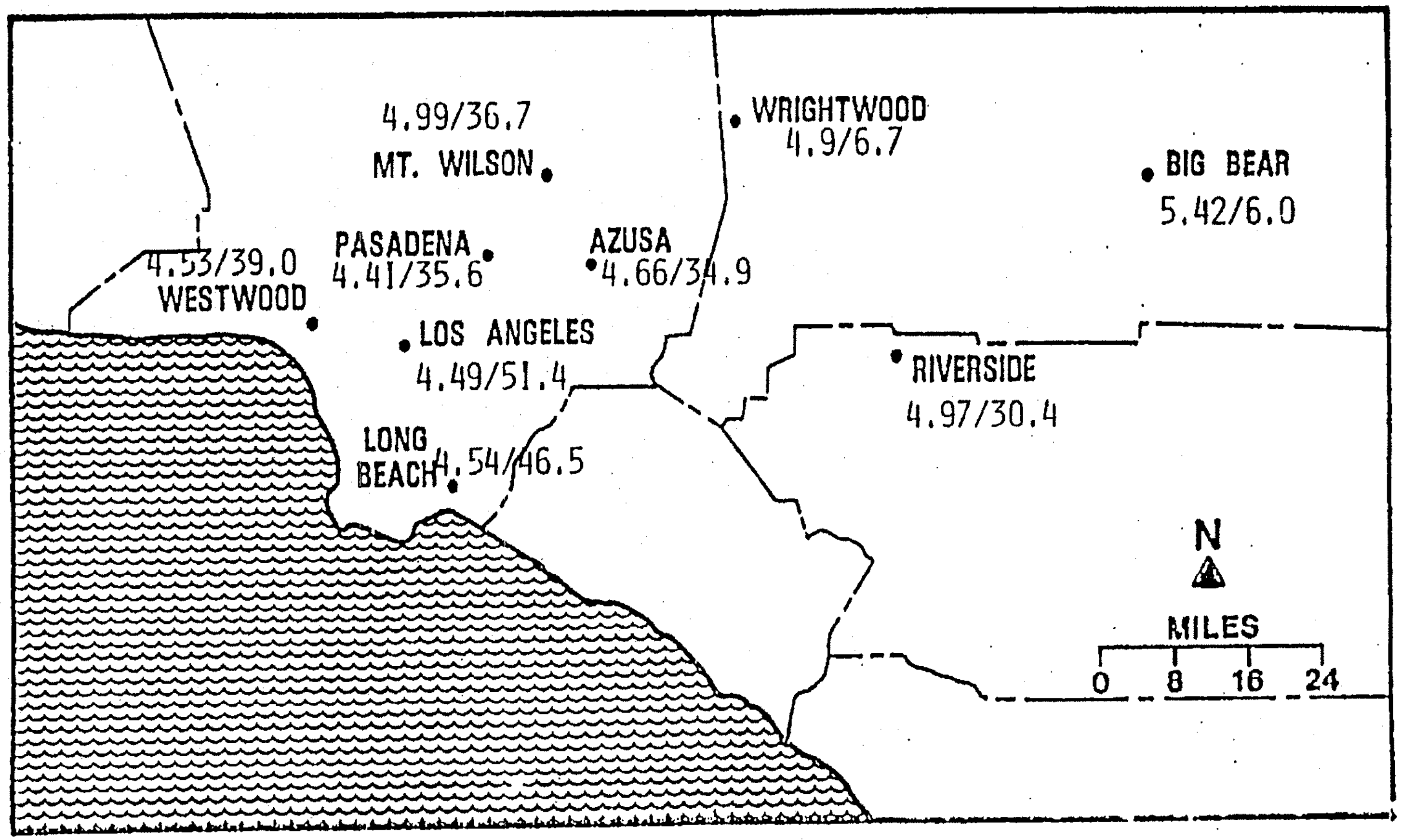
Another air pollution problem related to sulfur dioxide emissions is acid precipitation. An increasing amount of scientific research suggests that acid deposition, either as precipitation or dry deposition, may be responsible for long-term adverse environmental effects.[23/] These effects include the acidification of lakes, rivers, and groundwaters; damage to biota in aquatic ecosystems; possible changes in forests and agricultural crop productivity; demineralization of soils; deterioration of man-made materials and degradation of drinking water systems.[23/] It is not known whether these effects are occurring in California, but such effects have been documented elsewhere. Both sulfates and nitrates in the atmosphere contribute to the acidity of rain. Researchers under contract to the Air Resources Board have reported that in the South Coast Air Basin the ratio of non-sea salt sulfate to nitrate in rainfall is 0.9.[24/] Thus, sulfur dioxide emissions are nearly as important as nitrogen dioxide emissions as precursors to acidity of rainfall in Southern California.

During the fall, winter, and spring of 1978-79, precipitation samples for nine locations in the South Coast Air Basin were collected and analyzed for acidity[24/]. In Figure VI-5, the mean pH* and sulfate values measured over

* pH is the negative of the logarithm of the hydrogen ion concentration in a solution and is a measure of acidity. Solutions with pH less than 7 are acidic. As the strength of the acid increases, the pH number decreases.

FIGURE VI-5

MEAN pH/NON-SEA SALT SULFATE VALUES
(μ EQUIV/LITER) FALL 1978 - SPRING 1979



Source: A Survey of Acid Precipitation in Northern California, Final Report, California Air Resources Board, 1980.

that sampling period are displayed. As the figure shows, rainfall throughout the Basin is substantially more acidic than unpolluted rain, which has a pH of 5.65. Typically, the precipitation was 10 to 100 times more acidic than unpolluted rain. At its worst, the acidity was nearly 1,000 times that of unpolluted rain. There are currently no standards regarding precipitation acidity.

> Independent Refiner's Association of California Comment: "Acid precipitation is not a new phenomenon. However, recognition that it is an environmental problem did not occur until fairly recently in California. Furthermore, the data base on acid preciptation is rather sparse.
>
> In recognition of this, Assembly Bill 2752 was passed by the Legislature and approved by the Governor on September 27, 1982.
>
> The bill provides funding mechanisms for very comprehensive studies of Acid Deposition under the auspices of the Air Resources Board over a 5-year period but prohibits the Air Resources Board from adopting any rules or regulations to control acid deposition without further statutory authorization.

c. Air Pollution Emergency Episodes

Based on health considerations, certain ambient concentrations of various pollutants have been designated by the Air Resources Board and the EPA as emergency episode levels.[25,26] When an air pollution episode level is reached, an air pollution control or air quality management district is required to take measures to abate activities which contribute to the high ambient concentrations of the pollutant for which the episode was declared.[25]

Table VI-4 shows the frequency of pollutant concentrations which equaled or exceeded air pollution episode criteria levels in the South Coast Air Basin for the years 1979, 1980, and 1981. As the Table shows, there were 105 first stage oxidant episodes, 5 second stage oxidant episodes, 6 TSP episodes, and 6 sulfate/oxidant episodes in the basin during 1981.

TABLE VI-4

AIR POLLUTION EPISODES IN THE SOUTH COAST AIR BASIN

1979, 1980, 1981

Pollutant/Episode[a]	Number of Episodes (Days)		
	1979	1980	1981
Oxidant - Stage 1 Episode[b]	123	102	105
Oxidant - Stage 2 Episode[c]	20	15	5
TSP Episode[d]	2	12	6
Sulfate/Oxidant Episode[e]	7	26	6

a/ Oxidant and sulfate/oxidant episode criteria are set by the Air Resources Board (ARB). The TSP episode criterion is an EPA criterion.

b/ ARB criterion - Oxidant concentration greater than or equal to 0.20 ppm.

c/ ARB criterion - Oxidant concentration greater than or equal to 0.35 ppm.

d/ EPA criterion for an "air pollution alert" - 375 ug/m^3. The ARB and the South Coast Air Quality Management District do not include TSP episodes in their emergency plans.

e/ ARB criterion - Sulfate concentration greater than or equal to 25 ug/m^3 in combination with an oxidant concentation greater than or equal to 0.20 ppm.

Source: Air Resources Board staff.

In addition to the episodes shown in Table VI-4, for the years 1979 through 1981 there were 6 first stage oxidant episodes in the South Central Coast Air Basin and 20 first stage oxidant episodes in the San Diego Air Basin. Also during that period, there were 3 second stage oxidant episodes in the San Diego Air Basin and 7 TSP episodes in the South Central Coast Air Basin.. There was 1 first stage oxidant episode in the San Francisco Bay Area Air Basin in the period 1979-1981.

C. COASTAL CALIFORNIA METEOROLOGY

California Coastal Waters have been defined as that area between the California coastline and a line starting at the California - Oregon border at the Pacific Ocean

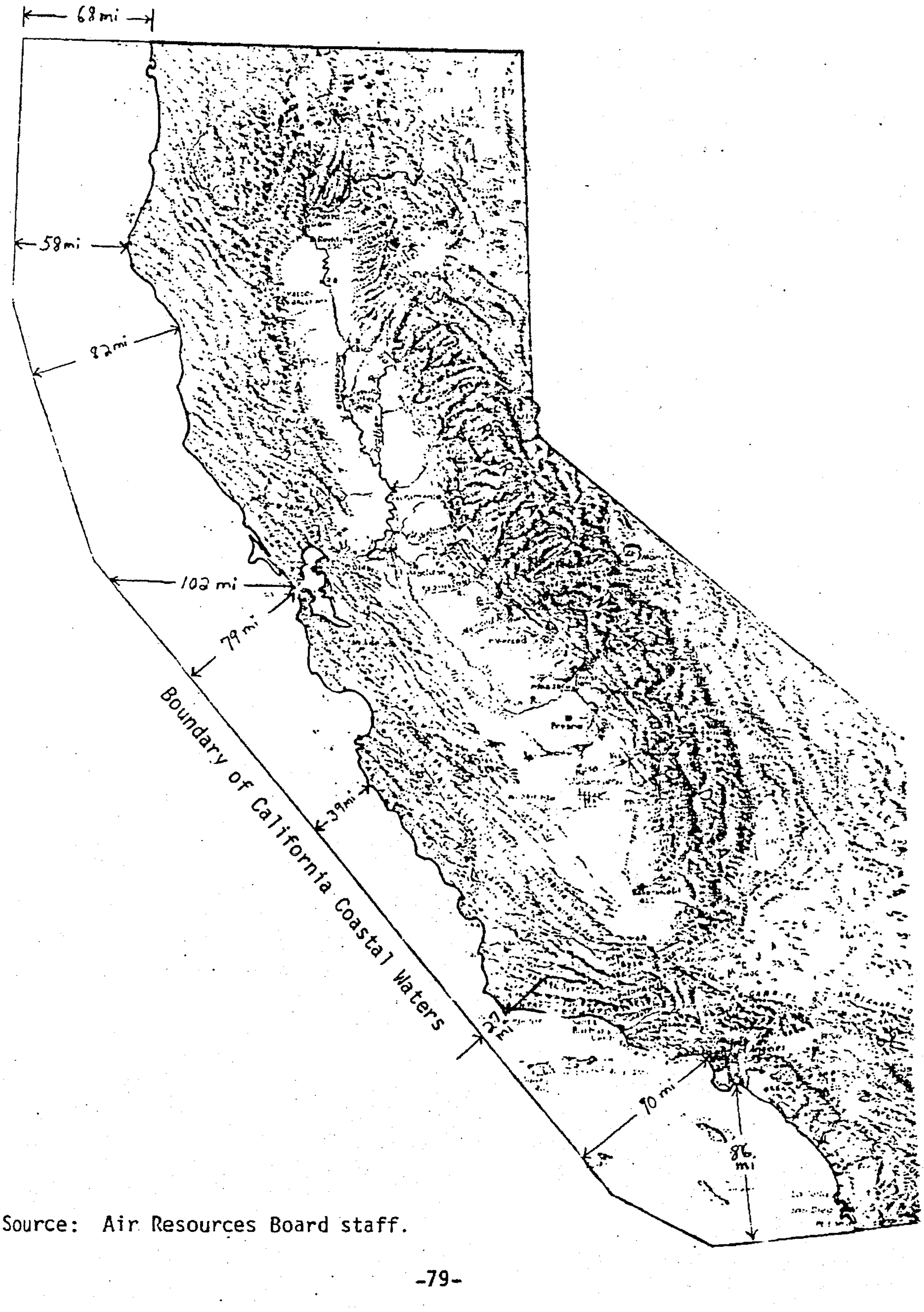
thence to 42.0° 125.5°W
thence to 41.0°N 125.5°W
thence to 40.0°N 125.5°W
thence to 39.0°N 125.0°W
thence to 38.0°N 124.5°W
thence to 37.0°N 123.5°W
thence to 36.0°N 122.5°W
thence to 35.0°N 121.5°W
thence to 34.0°N 120.5°W
thence to 33.0°N 119.5°W
thence to 32.5°N 118.5°W

and ending at the California-Mexico border at the Pacific Ocean. The California Coastal Waters are shown on Figure VI-6.

The line describing California Coastal Waters does not form a political boundary but it is useful in describing the fate of pollutants emitted off the California coast. The definition of California Coastal Waters was developed by the ARB meteorology staff and was originally presented as Appendix A to the ARB staff report, Status Report Regarding Adoption by Local Air Pollution Control Districts of Rules for the Control of Emissions from Lightering Operations, February 23, 1978. California Coastal Waters as defined above is the area offshore of California within which pollutants are likely to be transported ashore and affect air quality in California's coastal air basins, particularly during the summer. Pollutant emissions released somewhat to the west of these waters in summer are likely to be transported southward, parallel to the coast. Most coastal marine traffic passes 3 to 15 miles from

FIGURE VI-6

CALIFORNIA COASTAL WATERS



Source: Air Resources Board staff.

the coast, well within the boundaries of California Coastal Waters. Emissions released well west of these waters are likely to be transported southwestward, away from the coast.

Development of the definition of California Coastal Waters is based on over 500,000 island, shipboard, and coastal meteorological observations. These data were taken from official records of a number of agencies including the U.S. Weather Bureau, Coast Guard, Navy, Air Force, Marine Corps, Civil Aeronautics Administration and Army Air Force (see pages 11 and 12 of Appendix H-1).

> WOGA Comment: WOGA does not accept the State's definition of Calfornia Coastal Waters for the reasons outlined in its legal position paper in Appendix B.

The development of the definition for California Coastal Waters is discussed in detail in Appendix H-1. The primary meteorological features of the California coastal areas that cause pollutants emitted within California Coastal Waters to be transported ashore are discussed below.

1. Pacific High Pressure Cell

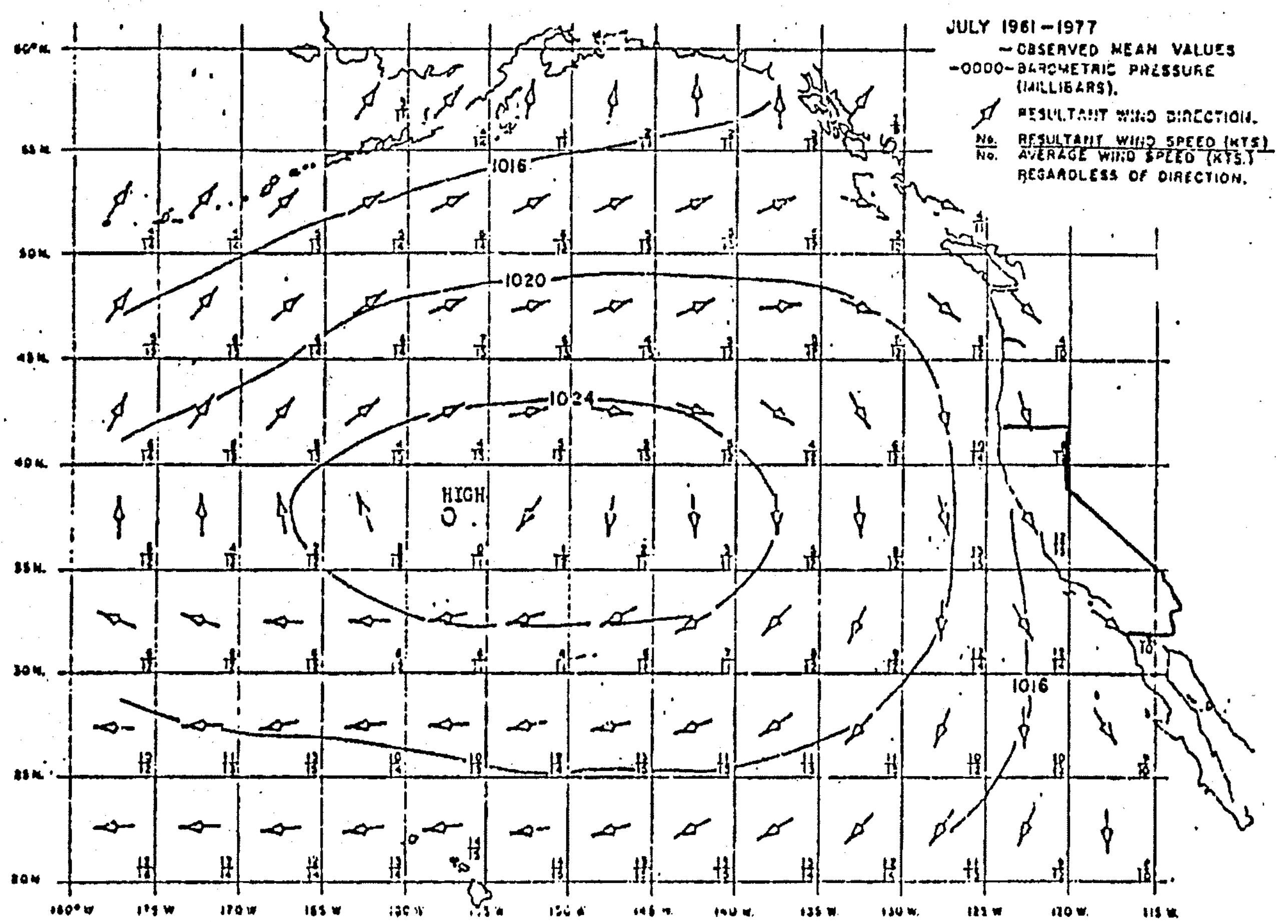
The North Pacific high pressure cell (anticyclone) is the dominant influence on the weather and climate of the eastern North Pacific Ocean and neighboring land areas in middle latitudes, particularly during the summer. It is a semi-permanent feature of the large scale atmospheric circulation pattern in the northern hemisphere and consists of an extensive deep mass of air rotating in a clockwise direction and covering much of the North Pacific Ocean throughout the year.[27/]

The basic cause of this circulation feature is the large scale thermal difference between adjacent water and land masses in middle latitudes.[27/] During summer, the water mass is much cooler than the neighboring land mass.

Through conduction and mixing, the air above the water is cooled and its density is increased thus producing a vast high pressure cell. In addition, air from the Equator enters the system aloft to provide additional support for high pressures. East of the ocean, the warm land increases the air temperature and consequently the air becomes less dense resulting in the formation of a large low pressure cell or thermal low. The positive differential of pressure from ocean and land causes a gigantic interchange of air. The warming air above the land surfaces rises and is replaced at low levels by cooler air moving onshore from the Pacific Ocean. A further interchange takes place aloft where air sinks in the Pacific high to replace the air that moved onshore. The sinking air in turn is replaced aloft by air from the tropics.

Because sinking (subsiding) air over the ocean is warmed by compression, it becomes warmer at lower levels than the air in the marine layer next to the ocean surface. The subsidence thus produces a strong persistent vertical temperature inversion which is another dominant feature of the Pacific high.[27/]

The Pacific high is strongest and most extensive in the summer when the temperature difference between the ocean and land is greatest. As the seasons progress and the sun moves southward, this ocean-land thermal discontinuity lessens and is displaced to more southerly latitudes as northern lands cool. This tends to weaken the Pacific high cell and causes it to move southward. The arrival of winter storms in middle latitudes also keeps the Pacific high somewhat suppressed thus reducing its influence in middle latitudes during winter.[27/] The average extent and location of the North Pacific anticyclone for the mid-summer and mid-winter months of July and January (seasonal extremes) are shown in Figures VI-7 and VI-8 respectively.

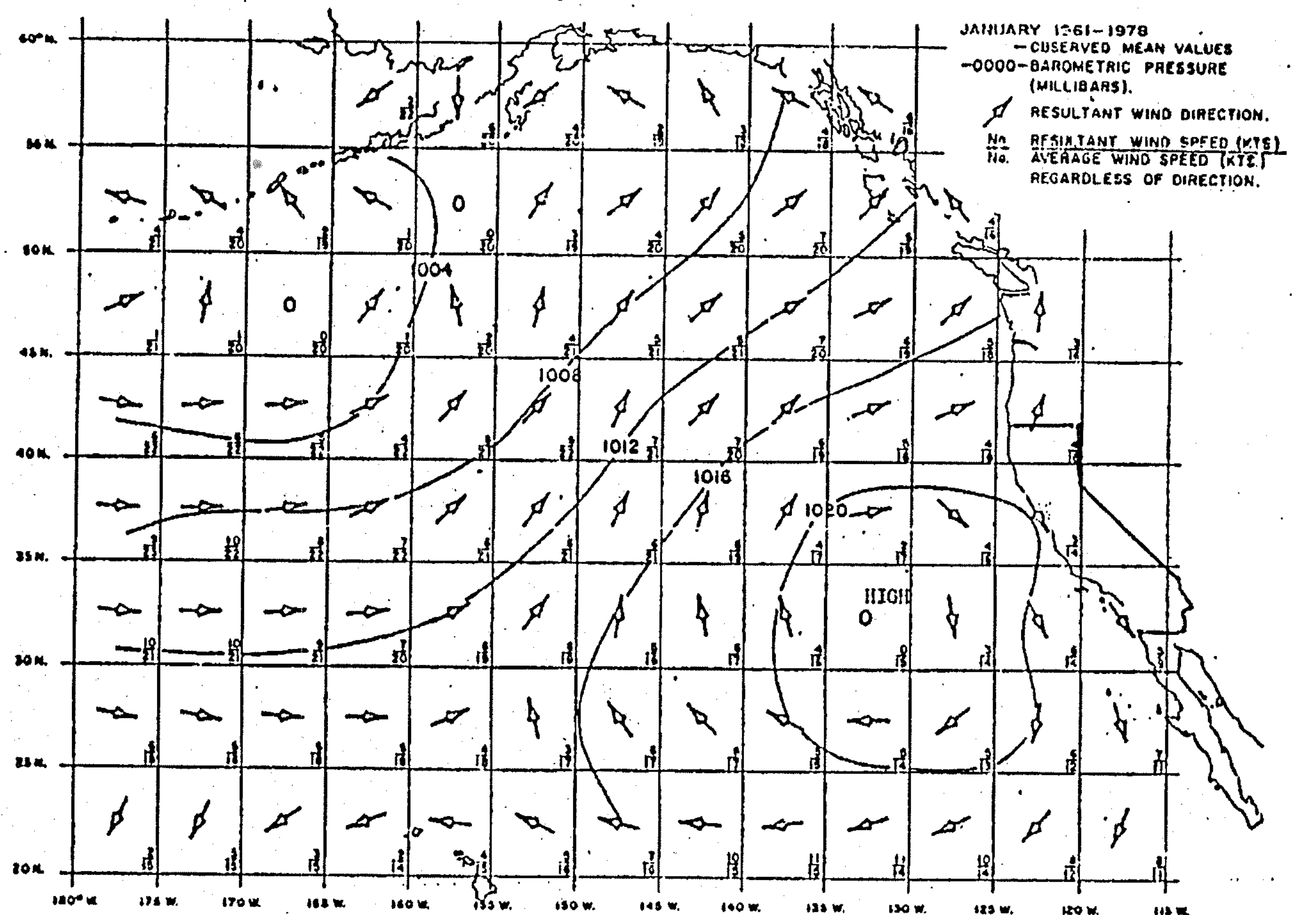


Mean July location of the Pacific High Pressure Cell. Resultant winds are shown for each 5° latitude and 5° longitude area. The wind speed numbers in the lower right hand corner of each area can be divided to obtain the steadiness ratio. Ratios between 0.7 and 0.9 (such as those found off the California coast) indicate the resultant winds are representative. Low ratios (such as those found near the center of the high cell) indicate that the individual winds varied markedly from the resultant wind direction.

FIGURE VI-7

MEAN JULY LOCATION OF THE PACIFIC HIGH PRESSURE CELL

Source: National Marine Fisheries Service, July 1977.



Mean Jan. location of the Pacific High Pressure Cell. Resultant winds are shown for each 5° latitude and 5° longitude area. The wind speed numbers in the lower right hand corner of each area can be divided to obtain the steadiness ratio. Ratios between 0.7 and 0.9 (such as those found off the California coast) indicate the resultant winds are representative. Low ratios (such as those found near the center of the high cell) indicate that the individual winds varied markedly from the resultant wind direction.

FIGURE VI-8

MEAN JANUARY LOCATION OF THE PACIFIC HIGH PRESSURE CELL

Source: National Marine Fisheries Service, January 1978.

2. Coastal California Predominant Wind Flows

The North Pacific high pressure cell produces a predominantly northwesterly flow of marine air over California Coastal Waters. This large scale circulation pattern is modified to a more westerly flow by continental influences as the air approaches the coast of California.[27/] Table VI-5 presents a summary of windflow direction frequencies measured at various locations along the California coast. The table shows that onshore windflows predominate during the spring, summer, and fall at all locations. The table also shows that the percentage frequency of offshore winds exceeds onshore winds in the winter at Vandenburg Air Force Base, Point Mugu, and Los Angeles. The greater overall frequency of onshore winds indicates a net transport of marine air, including the pollutant content of such air, into coastal air basins. This can be seen graphically in Figures VI-9 and VI-10 which show the predominant summer wind flow patterns along the coast of northern California and southern California respectively.

3. Land/Sea Breezes

The large scale climatological wind flows along the California coast as discussed above are modified by the effects of local land/sea breeze circulations. In effect, the local daytime sea breeze enhances the large-scale onshore component of the wind while the nighttime land breeze retards or on occasion reverses the flow.[28/] Table VI-6 presents seasonal resultant winds by time of day for Oakland and Point Mugu Naval Air Station (NAS) located just south of Oxnard. The table shows the influences of the land/sea breeze circulations and shows that the onshore winds are generally stronger than offshore winds, a further indication of the transport of

TABLE VI-5

Windflow Direction Frequencies in Coastal Areas of California

Station	Direction of Wind Flow	Seasonal Frequency in Percent				
		Spring[a]	Summer[b]	Fall[c]	Winter[d]	Annual
Oakland	Onshore	75%	83%	62%	47%	67%
	Offshore	20%	13%	27%	42%	25%
	Calm	5%	4%	11%	11%	8%
Vandenberg AFB	Onshore	64%	69%	48%	34%	54%
	Offshore	24%	9%	32%	53%	29%
	Calm	12%	22%	20%	13%	17%
Santa Barbara	Onshore	50%	62%	44%	32%	47%
	Offshore	26%	21%	29%	24%	25%
	Calm	24%	17%	27%	44%	28%
Point Mugu NAS	Onshore	57%	59%	41%	31%	47%
	Offshore	28%	21%	41%	54%	36%
	Calm	15%	20%	18%	15%	17%
Los Angeles	Onshore	68%	81%	60%	43%	63%
	Offshore	30%	16%	36%	53%	34%
	Calm	2%	3%	4%	4%	3%

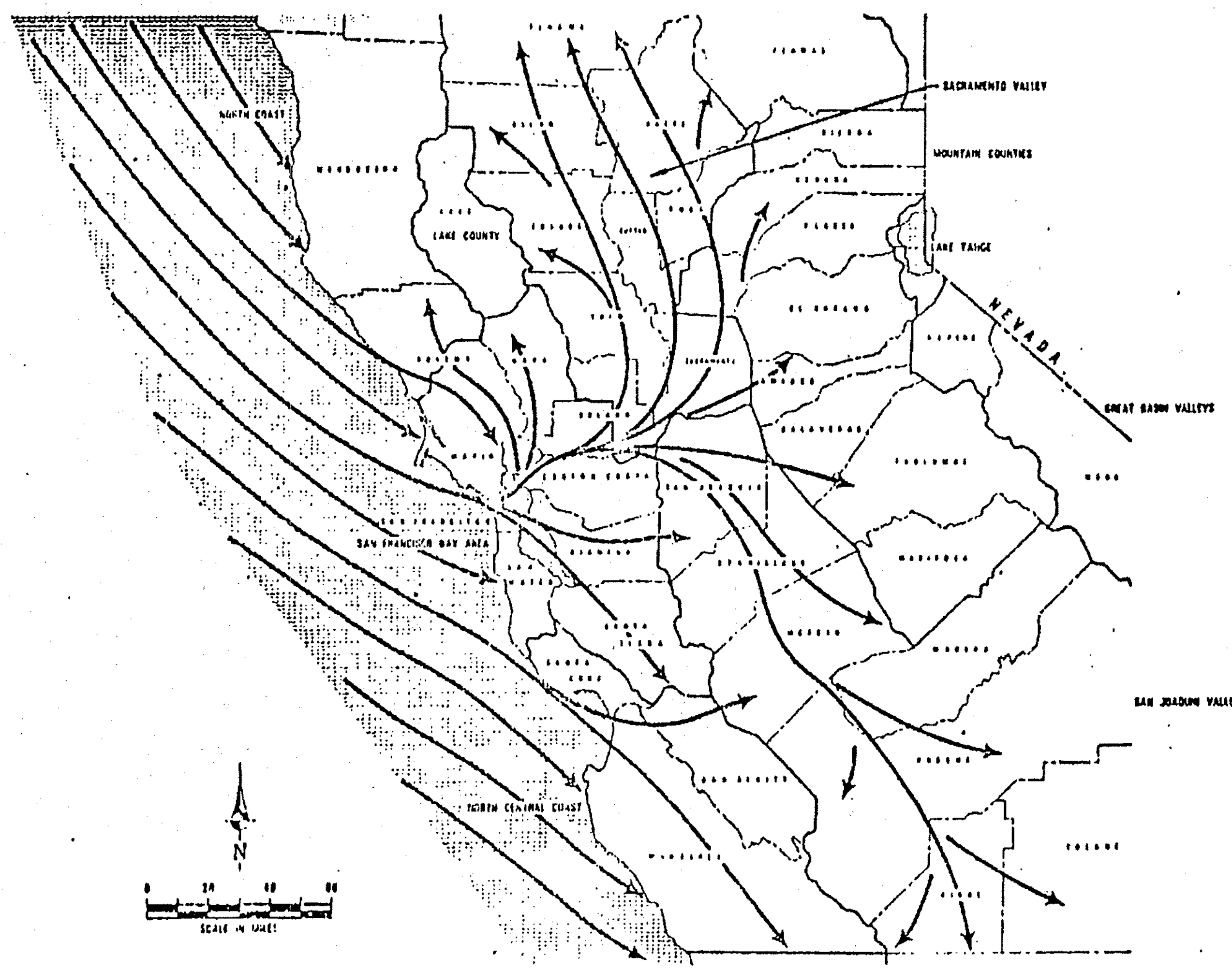
Period of Record: Oakland 1965-1978
Vandenberg AFB 1959-1977
Santa Barbara 1960-1964
Point Mugu NAS 1960-1972
Los Angeles International 1960-1978

[a] Spring: March, April, May
[b] Summer: June, July, August
[c] Fall: September, October, November
[d] Winter: December, January, February

Source: National Climatic Center

FIGURE VI-9

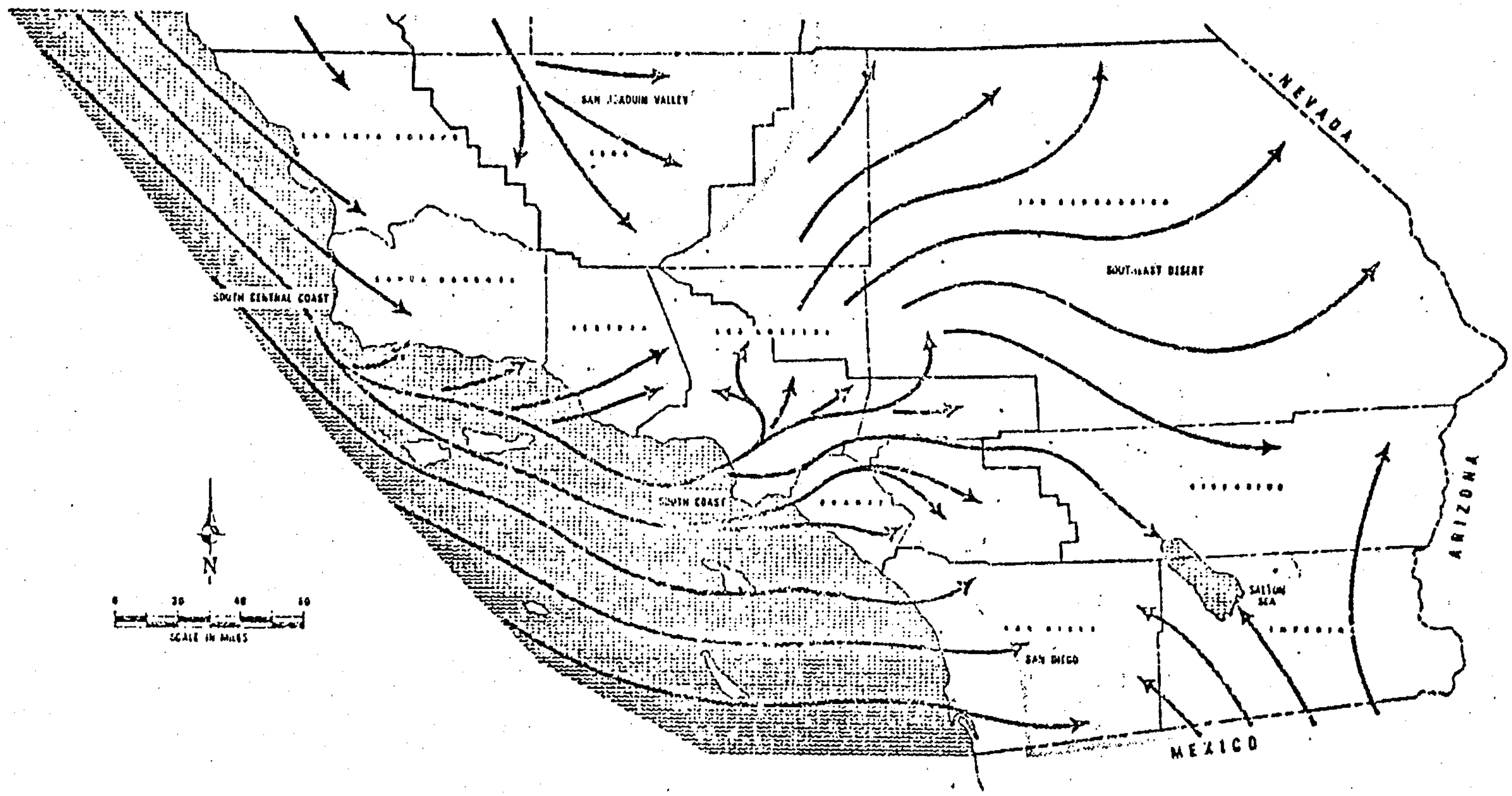
NORTHERN CALIFORNIA
PREDOMINANT WIND FLOW PATTERNS
SUMMER (JUNE, JULY, AUGUST)



Source: Air Resources Board Technical Services Division

FIGURE VI-10

SOUTHERN CALIFORNIA
PREDOMINANT WIND FLOW PATTERNS
SUMMER (JUNE, JULY, AUGUST)



Source: Air Resources Board, Technical Services Division

TABLE VI-6

Three-Hourly and Seasonal Resultant Winds
(Degrees/MPH - Onshore Winds in Parens)

Oakland

Time (PST)	Spring	Summer	Fall	Winter	Annual
0100	(270/4)	(280/6)	(300/1)	100/2	(280/2)
0400	(270/2)	(280/5)	020/1	100/2	(280/1)
0700	(230/1)	(270/4)	120/1	110/3	(220/1)
1000	(250/5)	(270/7)	(240/3)	150/2	(250/4)
1300	(270/9)	(290/11)	(280/7)	(260/4)	(280/8)
1600	(280/12)	(290/13)	(290/3)	(280/4)	(280/9)
1900	(280/9)	(290/11)	(300/6)	(320/1)	(290/7)
2200	(230/5)	(280/7)	(300/3)	080/1	(290/4)
All Hours	(270/6)	(280/8)	(280/4)	(190/1)	(280/4)

Point Mugu NAS

Time (PST)	Spring	Summer	Fall	Winter	Annual
0100	323/1	Calm	036/2	033/4	024/1
0400	007/1	029/1	032/2	036/4	030/2
0700	013/2	013/1	031/2	038/4	029/2
1000	(230/4)	(235/5)	(210/1)	052/4	(230/2)
1300	(250/8)	(252/8)	(248/5)	(230/2)	(249/6)
1600	(264/9)	(257/8)	(259/6)	(279/3)	(268/7)
1900	(279/5)	(287/4)	320/2	001/2	(297/3)
2200	(297/2)	(291/1)	002/2	022/3	340/2
All Hours	(269/3)	(264/3)	(301/1)	022/2	(288/2)

Period of Record: Oakland 1975-1979
Point Mugu 1962-1977

Source: National Climatic Center

offshore emissions to receptor areas onshore. The table also shows that the fall and winter resultant winds, whether onshore or offshore, are not strong winds, having resultant magnitudes less than 7 miles per hour at the coast at all times.

4. Windflows in the Santa Barbara Channel

Analyses of airflow patterns in the Santa Barbara Channel indicate that emissions in the Channel that are not transported to the Santa Barbara or Ventura County coasts are carried into the South Coast Air Basin.[28/] Figures VI-11 through VI-14 were presented to the California Coastal Commission on October 23, 1982, as part of Chevron U.S.A.'s testimony on the determination of consistency with the Coastal Zone Management Act for proposed exploratory oil wells that Chevron proposes to drill in the Santa Barbara Channel. The figures present the airflow patterns in the Santa Barbara Channel for daytime and nighttime in both winter and summer. Figures VI-11 and VI-12 show that the daytime airflows, both in summer and winter, will transport emissions in the Channel either to Santa Barbara or Ventura County, or to the South Coast Air Basin. Figures VI-13 and VI-14 show that the nighttime windflows in the Channel tend to carry emissions into Ventura County or into the Gulf of Santa Catalina off the South Coast Air Basin. The pollutants arriving in the Gulf of Santa Catalina can be carried into the Los Angeles area as the nighttime land breeze is replaced by the daytime sea breeze.

5. Atmospheric Inversion

The air that flows around the Pacific high at upper levels sinks (subsides) and consequently warms due to air compression. This warm air above the cool coastal marine air produces a strong and persistent vertical temperature inversion that is a major influence on atmospheric stability.